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ABSTRACT

This paper discusses recent studies of the adult visual evoked potential (VEP) which have indicated that specific components of the complex waveform obtained are related to the three basic color processes, and that these components interact in ways that seem to agree with opponent-colors phenomena. The components identified as being related to the three processes have time characteristics comparable to the relative time courses of the perceptual color responses, with red being the fastest, followed by green, and blue being the slowest to develop. In a study now in progress these techniques are being applied to a group of term infants. Preliminary results are discussed briefly. Findings seem to indicate that the technique evolved for the study of color in the normal adult can also be used for all age levels--thus to be possibly a valuable way of monitoring the development of color vision in the child. (MS)

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COLOR EVOKED POTENTIALS IN ADULTS AND INFANTS

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The attempts to identify components of the complex waveforms of the Visual Evoked Potential (VEP) which are related to the basic color processes, have been endemic in this field over the last two decades. Lord Adrian showed wavelength related phenomena in the electroretinogram (ERG) many years before the current interest in the "cortical" evoked potentials, and his findings must be reexamined in light of current work.

The controversial status of the color evoked potential work to date is the natural result of: (1) the complex nature of the phenomena involved; (2) the marked individual differences to be found (and expected); and (3) the highly divergent experimental techniques employed by various workers. Regan has covered the earlier work in this area in his book on the evoked potentials (reference 1), so it will not be detailed here.

As the result of more recent work in this area, it has become clear that the most effective approach is to use essentially that approach which has proven to be most effective in the psychophysical investigations of the color processes. This involves the selective desensitization of the visual system, using varying intensities of colored background lights to increase or reduce the effectiveness of the specific color processes. The most revealing example of this is the presentation of blue flashes of light superimposed on a varying yellow background.

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In the beginning condition, the yellow background is not present. It is assumed that in this case the blue stimulus activates almost exclusively the blue and green retinal processes, so the evoked potential obtained under this condition would presumably reflect some complex interaction of the electrical activity related to the blue and green processes. Since yellow consists of red and green wavelengths, raising the intensity level of the yellow background selectively desensitizes the green process, while leaving the blue process relatively unaffected.

Similarly, other optimal backgrounds could be chosen for obtaining evoked electrical activity related to the red and green processes--blue-green for red, and purple for green. From a practical point of view, however, it has been found that a yellow background works well for all conditions because of the high transmission factor of the yellow filters, which allow very broad ranges of background intensity.

The basic results to be described here are the outcome of years of work, both with color-normal and color-anomalous individuals. Further details may be found in the chapter by White, Kataoka and Martin in Desmedt's recent book on visual evoked potentials (reference 2).

On the basis of the many parametric studies which were carried out, it was found that there were indeed specific components related to the basic color processes, and that these could be differentiated on the basis of their temporal characteristics. Red-related activity appeared first, followed by green and finally blue-related activity. In the light-adapted situation, the red preceded the blue by about 50 msec.

In general, there were two components related to each of the three color processes, the second component appearing about 90-100 msec after the first. Further investigation showed that the two components probably were related to color-related activity taking place at different levels within the visual system.

One compelling piece of evidence for this was that the first component of each set could be recorded at both occipital cortex and eye level (with different polarities), while the second component was recordable primarily at the cortex only. The working hypothesis here is that the first component represents activity at least partly at some sub-cortical level, perhaps the lateral geniculate, which is known to be involved with color processing.

It is believed that the results of these color studies may be helpful in understanding the marked individual differences in the visual evoked potentials. Also, since the experimental approach gives us the ability to manipulate the various processes, we might be better able to begin to deal with such complex situations as the subtle variations in color sensitivity which have been reported in various disease entities and under drug-induced states.

Subsequent to the work summarized above, which established tentative norms for normal adults, and began to deal with individuals having specific color deficits, we have begun to gather evoked potential data from samples of various ages, using the techniques described. This will be a long process before meaningful age-norms can be established.

Most recently these techniques have been applied in the study of a group of neonates in the nursery at the Naval Regional Medical Center (Balboa Hospital) at San Diego. It is planned that about 50-60 children will be included in this study. At the time of this writing ten have been run.

The traditional neonatal evoked potentials have been produced by large flashes of light, usually white, produced by xenon flash lamps. More recently, patterned stimuli have been used in order to try to study the maturation of certain aspects of vision. There has also been earlier work with color stimulation of neonates, but not to our knowledge involving selective spectral desensitization.

The results of the early runs with the babies agree in general with all the other work in this area--great individual variability, very late components as

compared to adult records. Our special interest, however, was not in regard to these expected findings. Instead, we were looking for any evidence of the color-specific components which are so marked in the normal adult responses.

The raising of the background levels brought about drastic changes in the nature of the evoked potentials. The late peaks were very sensitive to any background changes, and at the higher background levels there were hints of components around 100 msec which might correspond to the adult color-specific components of the same latency. Compared to adult records these components were small indeed. This agrees, however, with what is known of the anatomy of the situation--at birth the color system is not well developed. Even a hint that we can detect color specific activity in the neonate is most important.

The results of what we have now seen in the records of the neonates lead to the conclusion that the technique evolved for the study of color in the normal adult can also be used for all age levels--thus to be possibly a valuable way of monitoring the development of color vision in the child.

References

1. Regan, D., Evoked Potentials in Psychology, Sensory Physiology and Clinical Medicine, Wiley, New York, 1972.

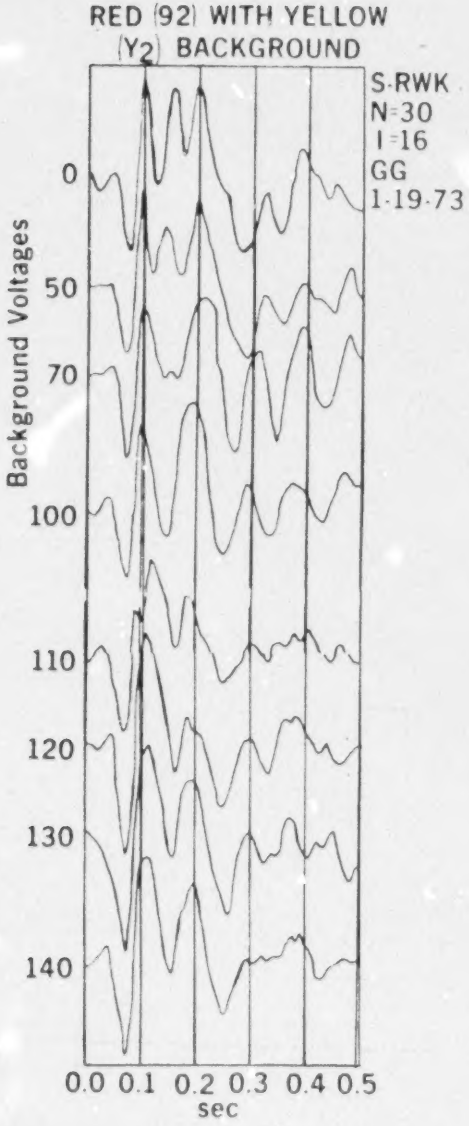
2. White, C. T., Kataoka, R., and Martin, J. I., Colour Evoked Potentials: Development of a Methodology for the Study of the Processes Involved in Colour Vision, in Visual Evoked Potentials in Man: New Developments, J. Desmedt (Ed.), Clarendon Press (Oxford), 1977, pp. 250-272.

Figure 1

An example of color evoked potentials in a normal adult. Colored light flashes produced by a xenon flash lamp with Wratten filters in front of it (Red, #92, or Blue, #98). Background levels controlled by a variac-controlled tungsten light passing through either a yellow or a blue-green filter. Increasing the voltage setting increased the intensity of the background light.

Figure 2

An example of a term infant's evoked potentials to red and blue stimuli. The 0 voltage setting represents the in-dark condition, and higher settings represent higher background levels of yellow light.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(Y2) BACKGROUND
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N=30
I=16
GG
1-19-73
Background Voltages
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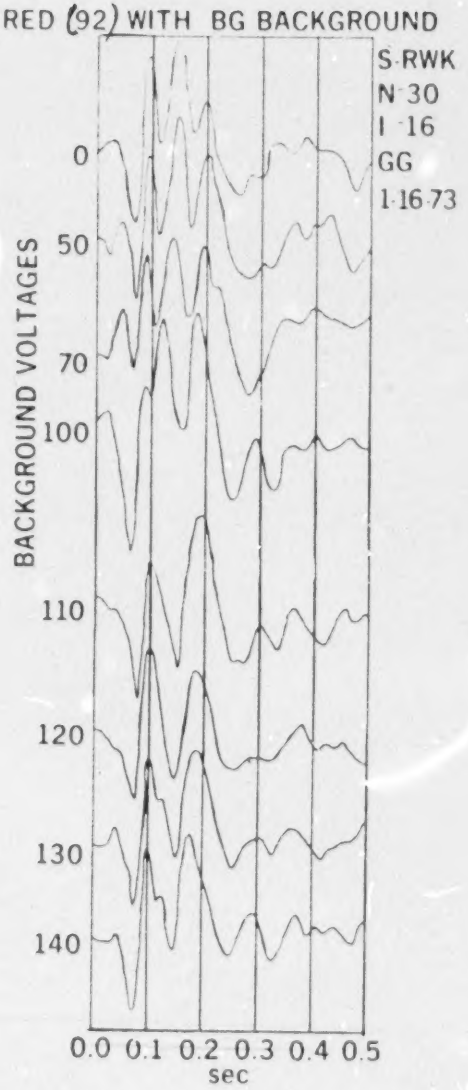
50
70
100
110
120
130
140
0.0 0.1 0.2 0.3 0.4 0.5
sec


RED (92) WITH BG BACKGROUND
S-RWK
N 30
I 16
GG
1-16-73
BACKGROUND VOLTAGES
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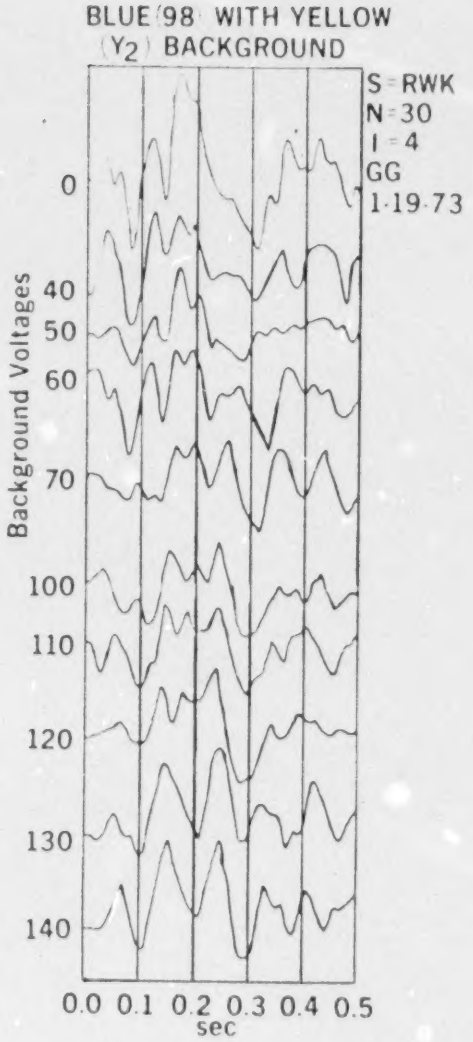
BLUE (98) WITH YELLOW
(Y2) BACKGROUND
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N=30
I=4
GG
1-19-73
Background Voltages
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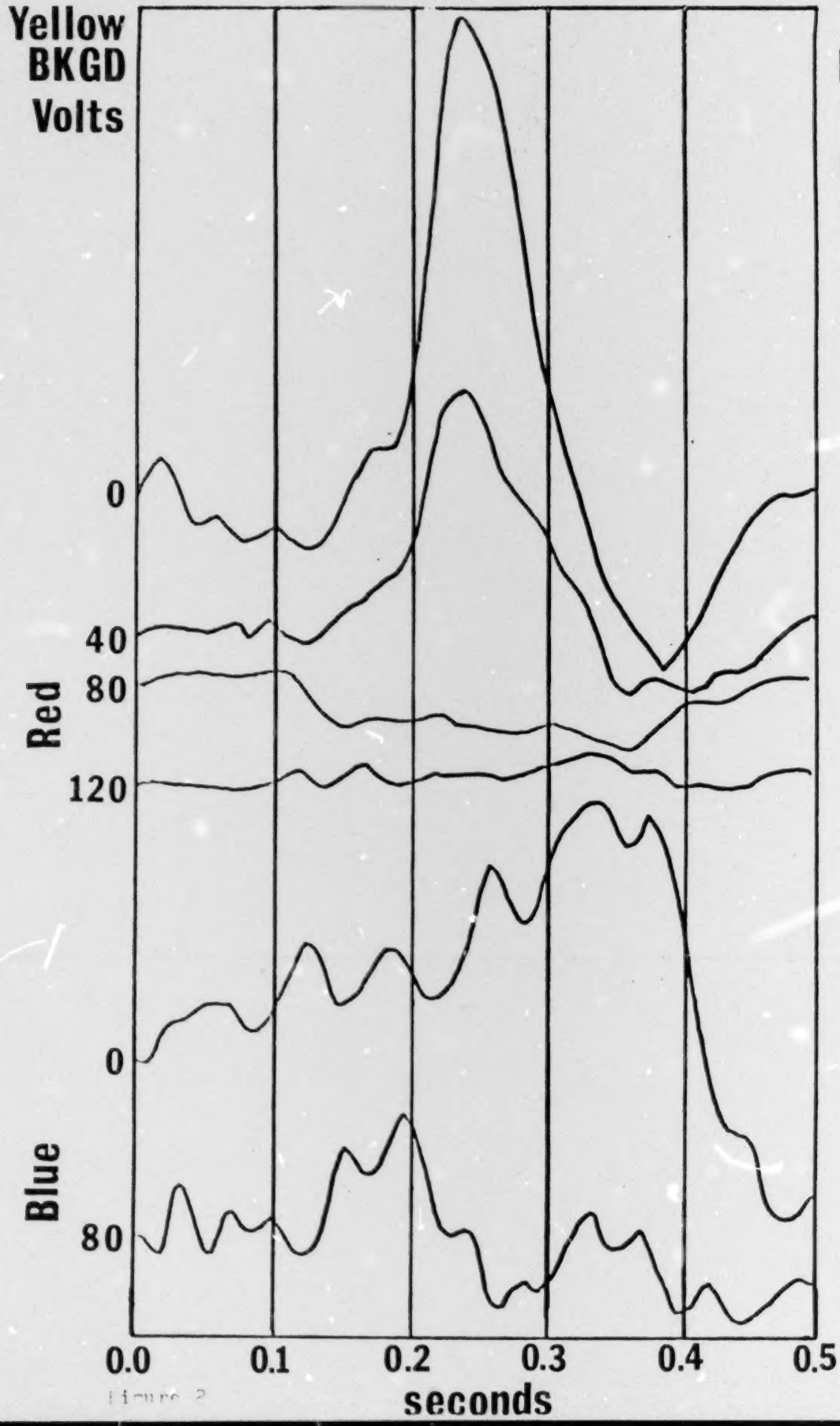
40
50
60
70
100
110
120
130
140
0.0 0.1 0.2 0.3 0.4 0.5
sec

Figure 1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BKGD
Volts
N=32
I=16
OU
Neg↓
0
40
80
120
Red
0
80
Blue
0.0
0.1
0.2
0.3
0.4
0.5
seconds

Figure 2